Insights on Technology Transfer from the Bureau of Mines

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ABSTRACT. The U.S. Bureau of Mines was established in 1910 to reduce the high accident rate in the nation's coal mines. For 85 years, it conducted a wide variety of tasks related to mining before it was abolished in 1995. The BOM had many technology transfer successes in its lifetime, including more than a dozen "R&D100" awards. This essay identifies and discusses five "transfer factors" that can explain the success (or failure) of many Bureau of Mines projects. These five factors are termed "pressure, pitfalls, path, price, and profit."

The Bureau of Mines (BOM), a federal government agency, was established in 1910 to reduce the high accident rate in the nation's coal mines. The BOM conducted a wide variety of tasks related to mining for 85 years. Although abolished in 1995, the BOM had considerable success with technology transfer during its lifetime. For example, in recent years the Pittsburgh Laboratory alone won 14 *Research & Development* "R&D100" awards and 6 Pollution Engineering "PE 5STAR" awards. Given the size of the Pittsburgh lab budget, this record is as good as the best research laboratories in the nation. Over the 85-year lifetime of the BOM, the mining accident rate significantly improved, progress that no doubt contributed to the unfortunate demise of the organization. However there are few events entirely devoid of opportunity, and the demise of the BOM presents the chance for a frank and open review of those factors that contributed to the technology transfer successes and failures of its mining research program.

The major technological accomplishments of the BOM were identified in a report by the National Research Council (NRC, 1990). Starting in 1970, these were: (1) more complete coalbed extraction technologies, (2) coal mine illumination, (3) methane drainage, (4) self-contained self-rescuers, and (5) respirable dust control. I examined the characteristics of these five accomplishments along with several dozen other technology transfer successes to generalize about key "transfer factors"—those factors that influenced the technology transfer success of specific projects.

1. Transfer factors

An analysis of BOM projects reveals five factors that create both opportunities and barriers to successful technology transfer. These transfer factors are:

- **Pressure**—financial or legal pressure from external sources.
- **Pitfalls**—problems that seem obvious in hindsight.
- **Path**—the length of the path necessary to transfer the technology.
- **Price**—the cost of the technology.
- **Profit**—how much the user can profit by using the technology.

Each of these is discussed in more detail below.

Pressure.—External pressure was the first factor that influenced whether project results were used by the mining industry. This pressure came from many different sources, the most effective

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being financial or legal. Two of the five accomplishments from the NRC report were coal mine illumination and self-contained self-rescuers. Both were required by coal mine health and safety legislation. (In a heavily regulated industry like mining, some impact of government regulations is never far away.)

Mine air monitoring systems developed by the BOM provide another example of how external pressure can promote technology transfer. These are electronic systems that monitor the quantity and quality of ventilation air. Since mine safety laws allow the use of substitute technologies that improve safety, mine operators used monitoring systems to gain relief from manpower-intensive activities such as checking for explosive gas.

Pitfalls.—The second transfer factor is the need to avoid pitfalls that come from not doing the necessary homework. For example, a mining research organization in Europe recently developed a rock dust meter that gives the percentage of rock in the dust lying on the coal mine floor. This percentage is important to know because it changes the explosivity of the dust. Unfortunately, this rock dust meter contained a radiation source. Because of regulations on radiation, it meant that every coal mine wishing to use the meter had to hire a new person responsible for radiation safety. You can imagine what happened. Relatedly, some BOM projects did not consider infrastructure needs. For example, in the 1970s BOM developed underground communications systems two or three generations beyond those in use, and for which most mines had no infrastructure to service and maintain. Failure to consider such technology transfer pitfalls was a major barrier to the implementation of many research projects.

Path Length.—Path length is the third key factor that can affect technology success. This factor represents the length of the path necessary to transfer the technology. The two basic paths are those that lead to a *technique* and those that lead to a *product*. The rock dust meter and mine communications systems were products. These innovations required a longer path—involving the participation of an intermediate party, a manufacturer—between the government and the user.

When the result of research is a technique and not a product, the chance of technology transfer success was always higher for BOM projects because the path was shorter. For example, two of the five major accomplishments listed by the NRC were methane drainage and respirable dust control. Both were techniques. In the case of methane drainage, if a mine operator wished to drain methane from his coalbed, he only needed to hire a driller. That driller followed a procedure that started in BOM research—where to drill the hole, what diameter, how deep, how to case it, what fracture treatments were necessary, and so on. In respirable dust control, the research was directed toward simple techniques that mines could carry out themselves.

Other BOM technology transfer successes involving techniques included engineering tools (such as expert systems or ventilation software), a coal mine roof rating system, a test procedure to measure the gas in coal, criteria for evaluation of explosion-proof seals, strategies for deployment of carbon monoxide sensors, and a new conveyor belt flammability test.

This success with techniques can be contrasted with the success the BOM had in developing instrumentation products. In the 1970's, the BOM funded a contract to develop a dust monitor based on forward light scattering. The result was GCA Corporation's RAM-1 monitor, a commercially successful product. However, there have been many that were not so successful—a diesel-discriminating fire smoke detector, a very novel carbon monoxide detector, and a remote methane sensor. The BOM even had its own rock dust meter that did not use radiation but still was not used.

This lack of success with instrumentation occurred for several reasons. One was a perceived lack of a market in the eyes of prospective manufacturers. Equipment purchases in a commodity-based industry like coal are often made to lower the overall cost of doing business; for example, a health and safety product purchase should result in lower health and safety costs. In the eyes of prospective manufacturers, many BOM instrumentation products simply did not meet this market test. Other important factors for prospective manufacturers were the size of the investment required and a perceived lack of adequate protection from patents and exclusive licenses.

Price.—Price was the fourth factor that influenced whether a BOM technology got used. In the BOM dust control program where I worked, price was the major factor. There was external pressure from government regulations, and most dust control developments were techniques rather than products. With those two considerations aside, what was adopted by industry depended on the cost. This included purchase *and* operating costs. For example, we had no success with high pressure (1000 psi) water sprays as a technique for dust control. Our research showed that high pressure sprays lowered dust by 40 percent. However, the downside was a $150,000 price tag, some operating problems, and a possible safety hazard from high pressure hoses.

Profit.—The cost issue has another side that represents the fifth transfer factor—profit. If the BOM devised a safety product or technique that was likely to raise productivity and increase profits, then the likelihood of implementation went way up. For example, in the 1970s the BOM developed a dust scrubber for continuous mining machines. This device lowered the amount of dust produced by the machine by 90 percent or more. Although it found some use, widespread application lagged for a decade until mine operators discovered that a dust scrubber permitted changes in the mining cycle that yielded a 5–10 percent gain in productivity. Today, most continuous mining machines have a dust scrubber.

It is instructive to examine two projects that represent the opposite ends of the success spectrum. One of the most successful BOM research projects was methane drainage; that is, the removal of methane gas from coalbeds before it escapes into the mine air. The National Research Council cited its success. Mining engineers from other countries laud it. The transfer factors were positive. For example, there was pressure to degas coalbeds because methane gas in many deep mines was creating an explosion hazard. The research resulted in techniques rather than products. Finally, tapping this source and selling the gas offered the chance of profit. Today, 5 percent of natural gas production in the United States comes from coalbeds. That is a major technology transfer success.

Much less successful was the BOM effort to build a hydrogen-powered shuttle car. A shuttle car is a truck-like vehicle that carries coal from the mining machine to the conveyor belt system. Most shuttle cars are powered by electric motors —perhaps 10 percent are diesel-powered. The diesels emit soot that could be a health hazard *but* there were no regulations limiting soot. Adoption by the industry would have required the manufacture and sale of an expensive product without any clear productivity benefits. There was no infrastructure for the distribution of large quantities of hydrogen, let alone transporting it down a mine shaft several miles to where the shuttle cars operate. While the emissions from a hydrogen-fueled engine are harmless, there were many safety concerns about the storage and handling of hydrogen. In summary, there was no pressure to use a hydrogen-powered shuttle car. It was a $250,000 product loaded with pitfalls and offering no productivity increases.

2. Conclusions

These experiences of the BOM are not particularly novel. Twenty years ago, A.D. Little conducted a study of six prominent federal programs of the early 1970s—nuclear power, coal combustion, motor vehicle safety, urban mass transportation, soy protein, and biological pesticides. Four of the six were rated poorly, but the study report did point out that successful commercialization of federally funded—R&D is nearly always accompanied by public policy measures that cause or stimulate market demand.

However, the experience of the Bureau of Mines illustrates that these market demand forces, expressed more specifically as transfer factors, operate even at a small project level scale. In hindsight, when transfer factors are considered, it is not difficult to see why the winning projects won and the losing projects lost. Researchers who consider pressure, pitfalls, path, price, and profit in selecting their project work enjoy a more successful career than those who do not.

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